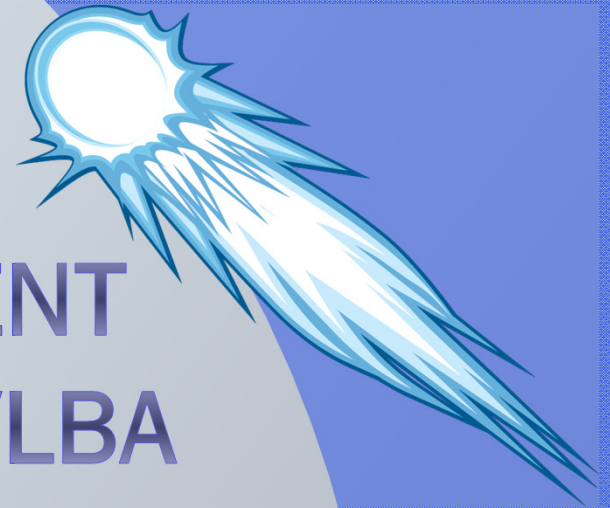# V-FASTR :
# COMMENSAL TRANSIENT DETECTION WITH THE VLBA

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Contact: `kiri.wagstaff@jpl.nasa.gov`
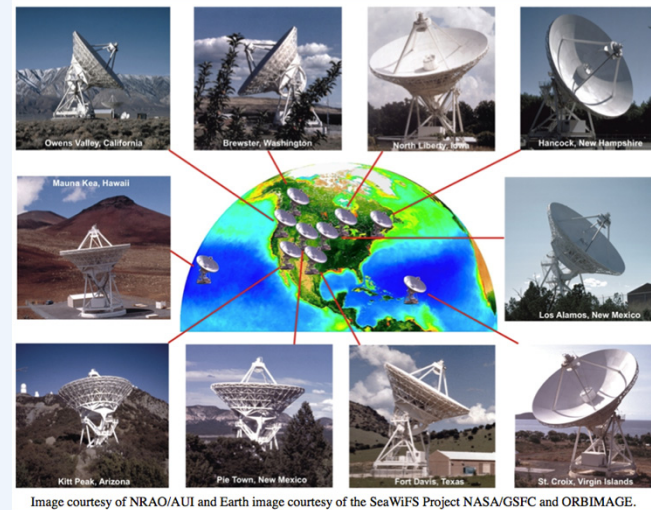
# Why fast radio transients?

- Excellent probes of ISM, IGM via dispersion measure (DM) and rotation measure (RM)
  - Laboratories of compact sources, extreme astrophysics
- Known sources and targets
  - Intermittent pulsars (RRATs), giant pulses, merging neutron stars
- Exotic sources
  - Black hole evaporation
  - Gravitational wave events
  - Extra-terrestrial intelligence?
  - Etc.
- Largely unexplored space. New discoveries await!
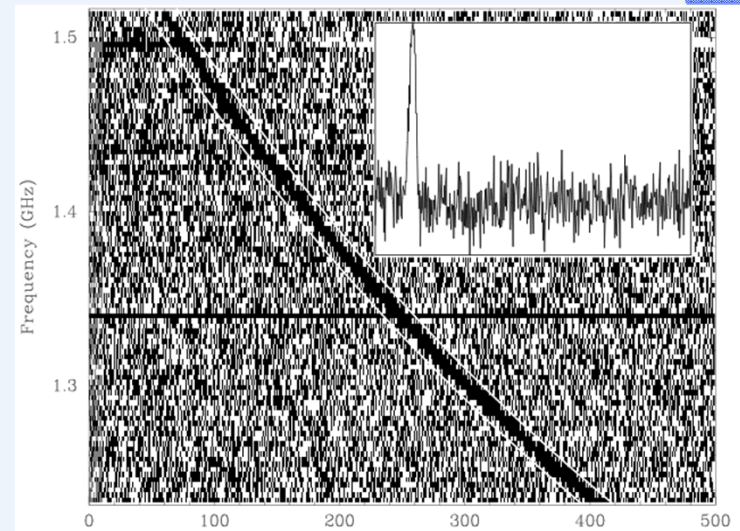


[Lorimer et al., 2007]

# Very Long Baseline Array

- 10 25-m dishes
- Data recorded to disk at each telescope, shipped to Array Operations Center in Socorro for correlation



Image courtesy of NRAO/AUI and Earth image courtesy of the SeaWiFS Project NASA/GSFC and ORBIMAGE.

- Correlation by DiFX software correlator [Deller et al., 2007]
  - Software correlators are flexible!
  - Can get autocorrelations with short integration times (1 ms), virtually for free (nothing's for free)

# V-FASTR: FASt TRansient Detection

- Trailblazer for CRAFT survey science project for ASKAP
- Goal: continuously detect fast (< 5s) radio transients
  - Commensal detection: Analyze VLBA filterbank data in real-time as it flows through the DiFX software correlator
  - Minimal impact to correlator operations
  - Detect transients even in campaigns with other observing goals
- Fast "trigger" decision to save buffer for offline analysis
  - Dramatically reduce data volume for next stage of analysis
- Innovations
  - Adaptive behavior using injected (known) pulses
  - Machine learning for multi-station detection and RFI excision
- Now running 24/7 on all VLBA observations
  - Detections to be shared with PIs first

# V-FASTR Architecture
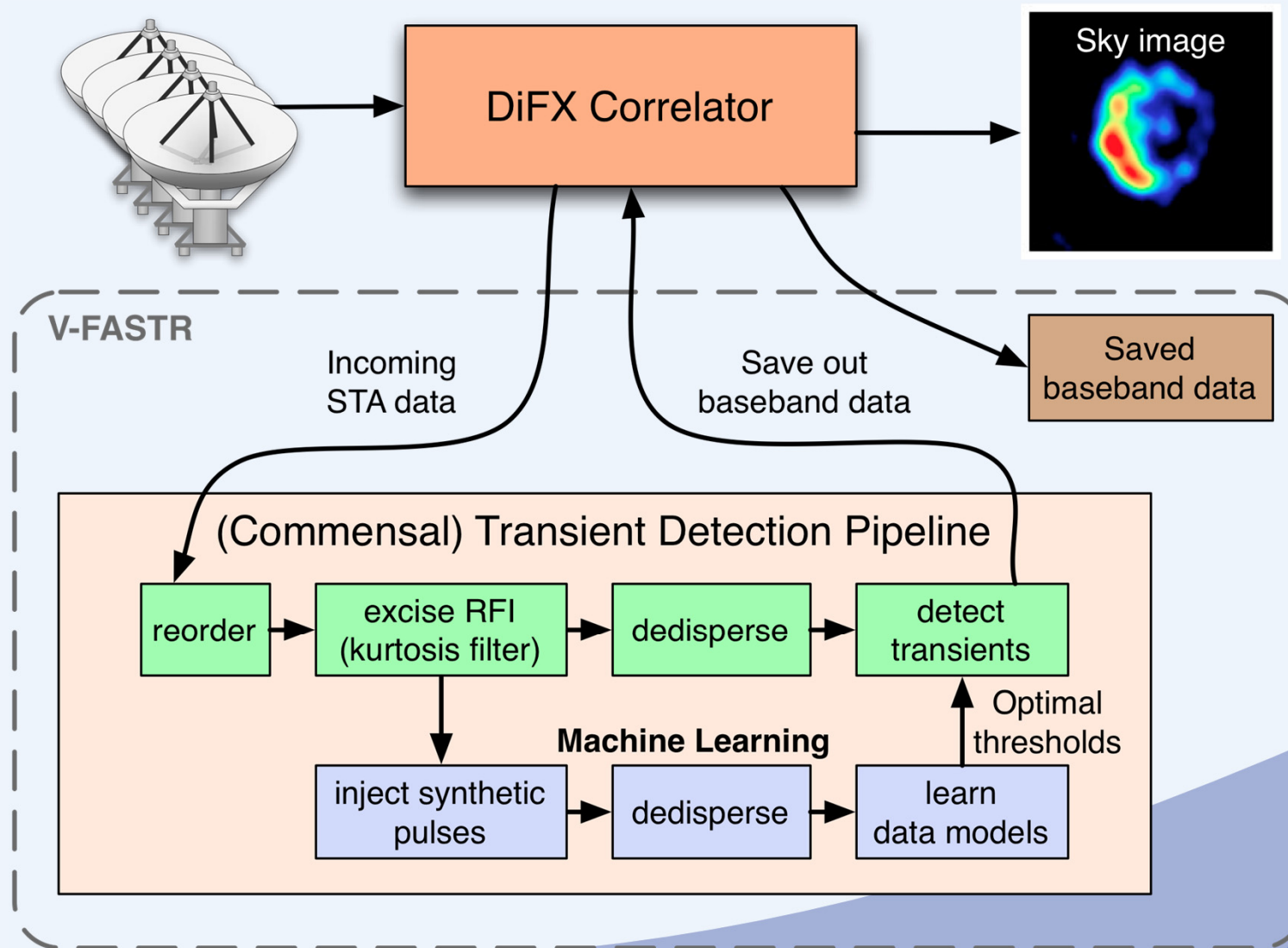
# Example VLBA Data

- ◉ **Pulsar B0329+54**
  - DM 26.8 pc/cm$^3$
  - Period: 714 ms

- ◉ **VLBA observations**
  - 1.4-1.674 GHz
  - 1 ms integration time
  - 9 scans, each lasting 242 s

pulses



Timestep
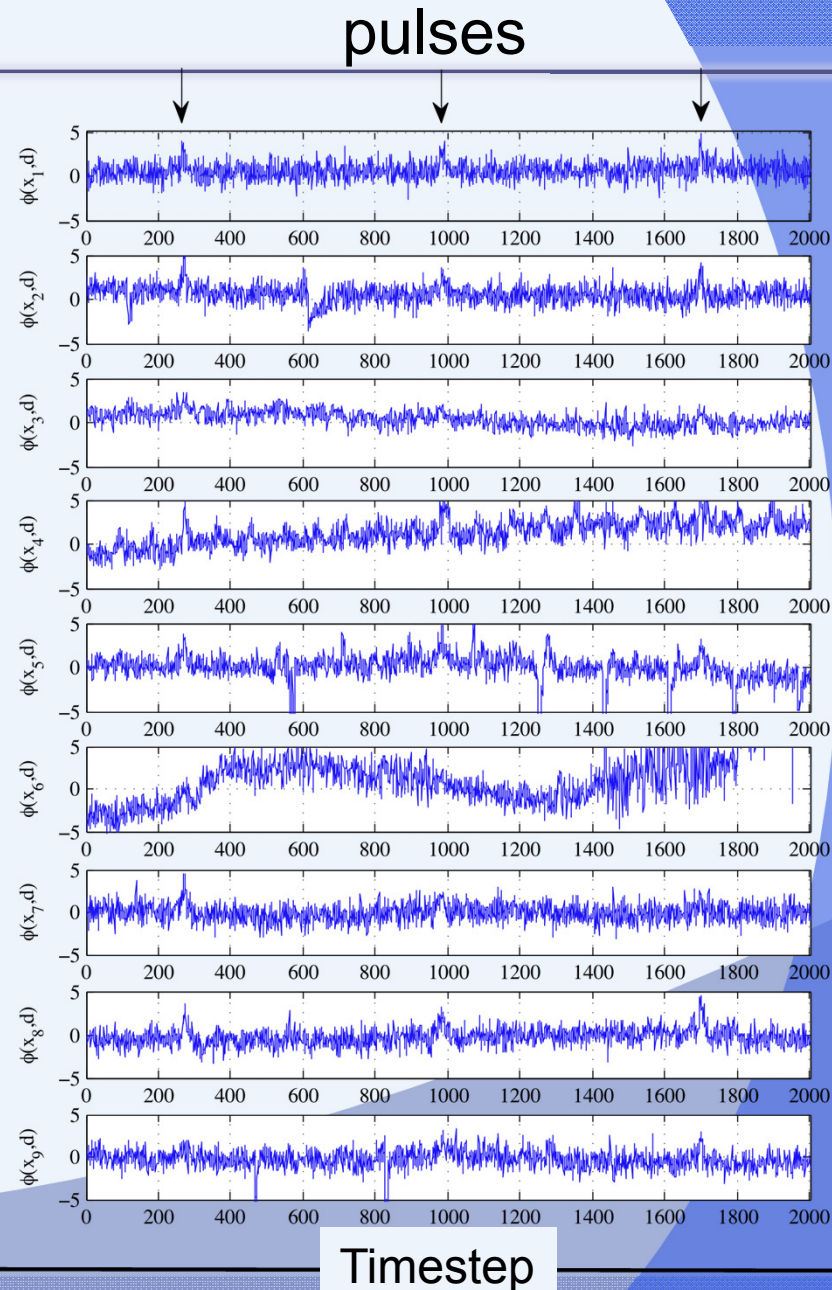
# Robust Summation

- Incoherent summation: sum power across all stations

$$\max_{DM} \frac{1}{A} \sum_{a=1}^{A} S_a(DM)$$

- Robust summation: omit min and max stations from sum

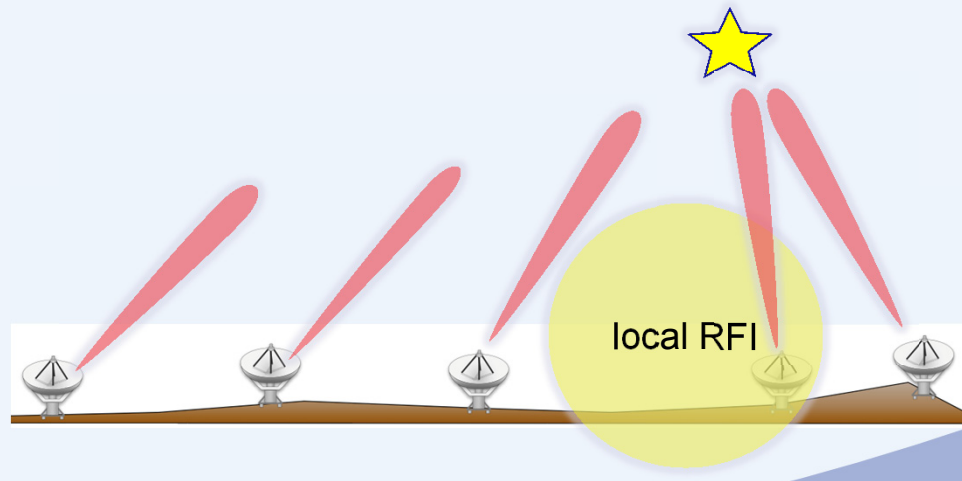$$\max_{DM} \frac{1}{A} \sum_{a=1}^{A-1} S_a(DM)$$

# Multi-Station Detection

- Learn model of data "background"
- Compute combined estimate that new signal is remote (observed by multiple stations)

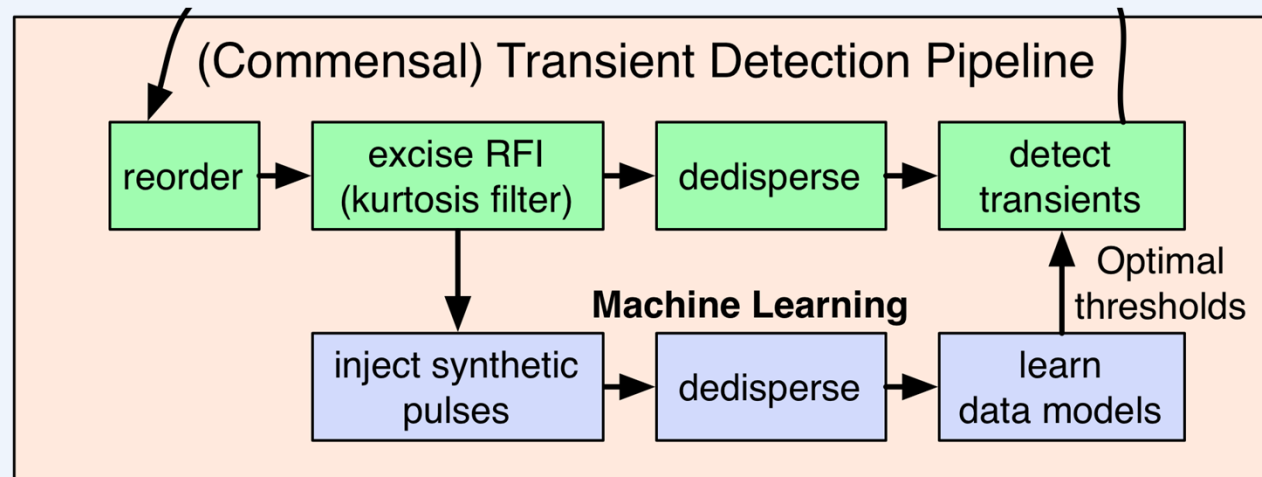$$\max_{DM} \frac{1}{A} \sum_{a=1}^{A} P(X \leq S_a(DM))$$

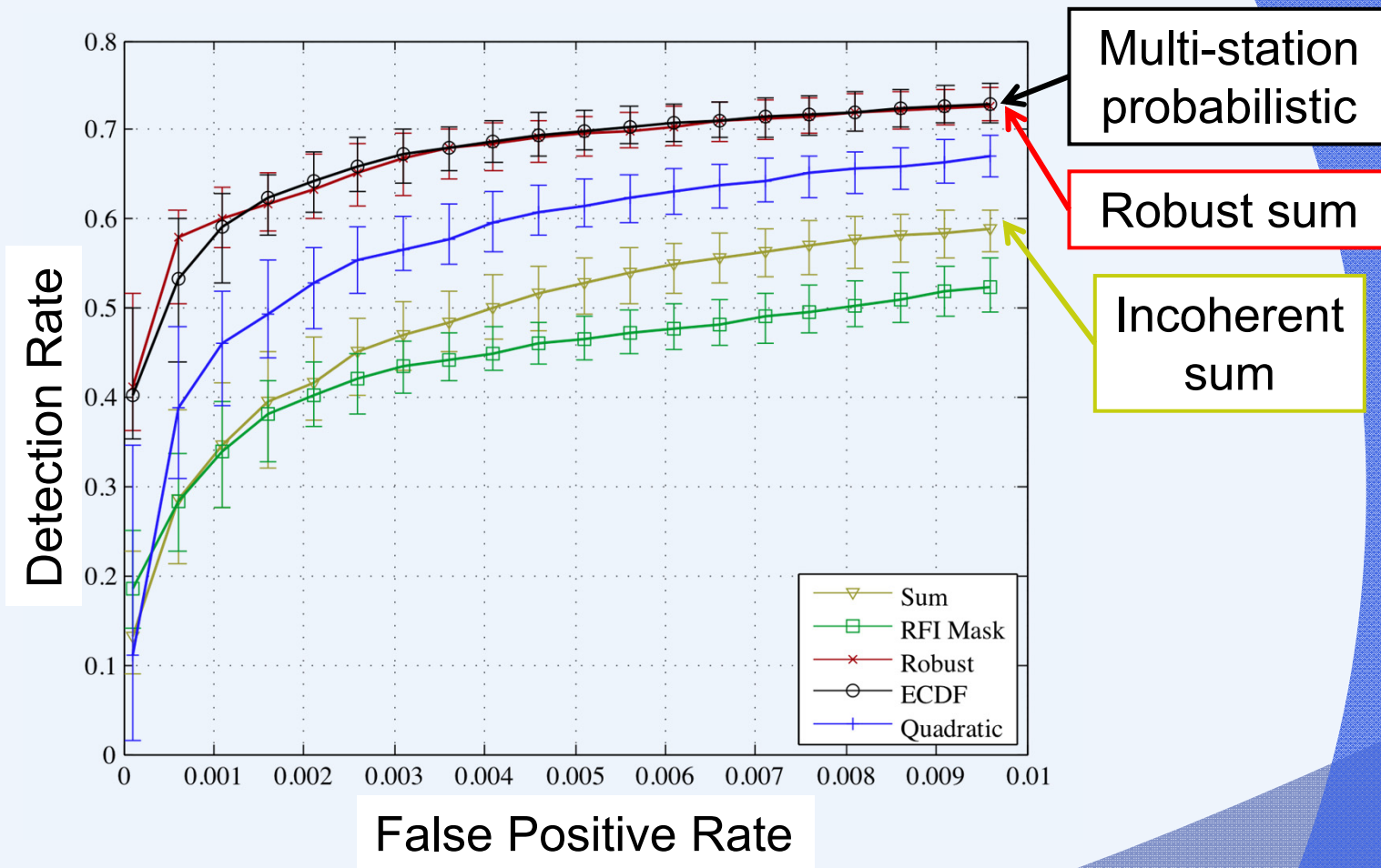- Improves sensitivity over incoherent summation



local RFI
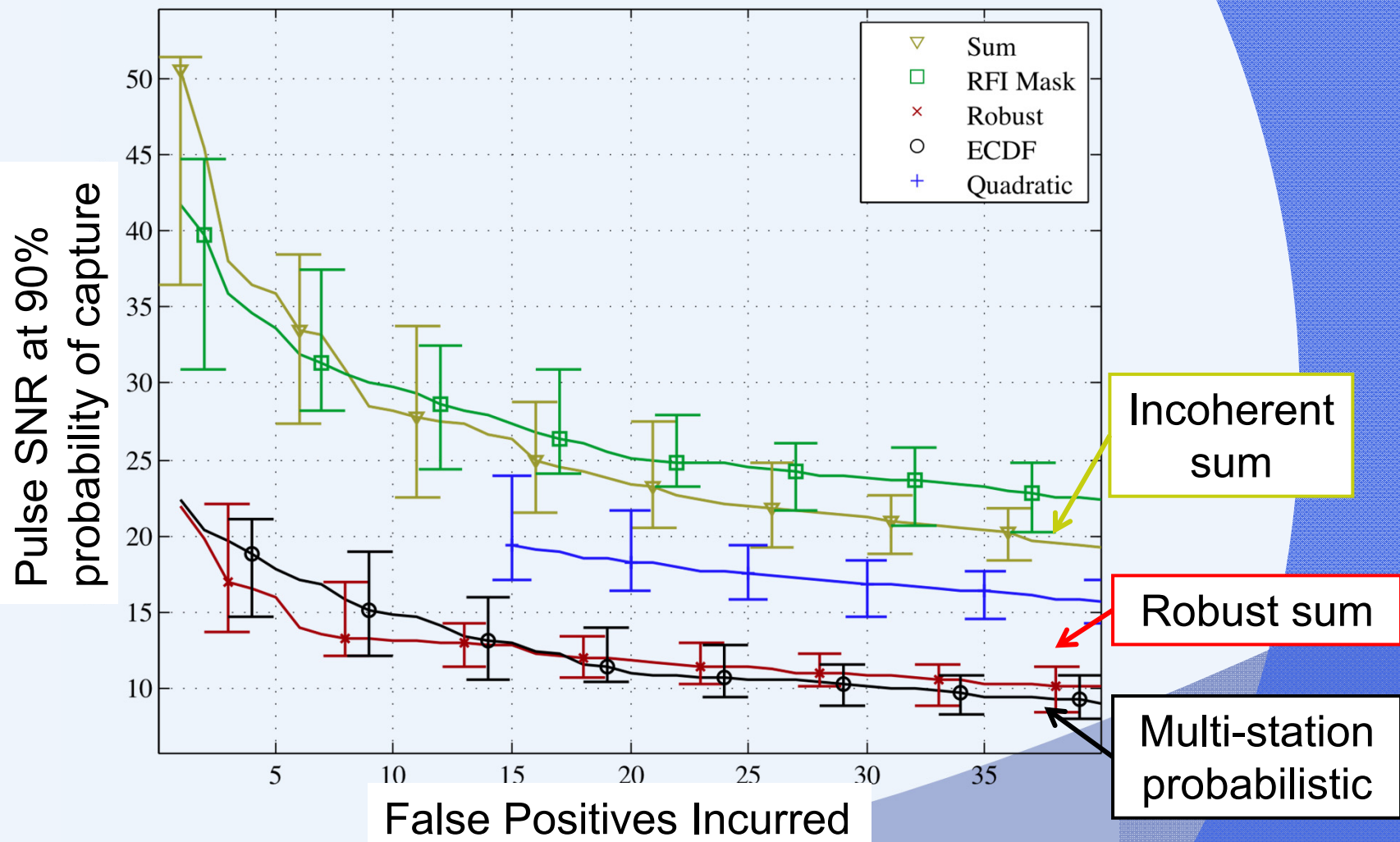
# Machine Learning: Adaptation

- Inject known (synthetic) pulses into data stream
- Adjust detection thresholds to maintain optimal performance

# Pulsar B0329+54 Detection Results

# Pulsar B0329+54 Sensitivity Results

# V-FASTR: Summary

- Now running 24/7 on all VLBA observations
- Value of real-time commensal transient searches
  - Detect events otherwise discarded even for campaigns uninterested in transients
- Machine learning enables better multi-station detection and adaptive detection thresholds
- Testbed for SKA-related concerns
  - Maintain acceptably low false alarm rate, real-time performance
  - Constrain buffer (disk) consumption for detections
  - Value of software correlator
- Raises issues in advance of the SKA
  - What to do with detections?  New policies needed?

# Thanks to…

- Dayton Jones, Joe Lazio, Bob Preston (JPL)
- JPL, NSF, NRAO, ICRAR (funding)